

# Absence of Prefrontal Lobe Dysfunction Indicators in Healthy Elderly Participants: Comparisons With Verified Prefrontal Lobe Damage

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Proficiency (errors) during the Conditioned Spatial Association Task (Milner & Petrides, 1984) was measured for groups of healthy elderly participants, university students, patients with no prefrontal neuropsychological impairment, and patients with prefrontal impairment. The results clearly demonstrated no significant group differences between the first three groups. We conclude that proficiency for tasks that require self-monitoring, structuring, and temporal ordering does not deteriorate quantitatively in healthy elderly adults. However, we did not assess the speed of information processing.

Normal aging has been associated with the gradual loss of (a) behavioral flexibility, (b) the capacity to self-monitor behavior, and (c) the efficiency (speed) of problem solving within nonstructured and novel settings. These domains of behavior are associated primarily with prefrontal lobe function (Stuss & Benson, 1986). Structural alterations in prefrontal organization, as inferred by enlargement of the anterior horns of the lateral ventricles and widening of sulci within the cerebral cortices, are expected correlates of geriatric progression (Terry & Hansen, 1988).

If alterations in prefrontal organization are that significant during normal aging, then healthy adults should display quantitative changes in tasks that emphasize flexibility, the reconstruction of the temporal order of events, and problem solving within nonstructured contexts (Persinger, 1992). The Conditioned Spatial Associa-

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tion Task (CSAT; Milner & Petrides, 1984), which involves learning the association between an array of lights and specific numbers, requires these domains of behavior to be both integrated and functional. This task has been very effective in discriminating patients with prefrontal lobe damage due to closed head injuries (CHI) from those who have not sustained these injuries. The present experiment was designed to determine if comparable deficits were discriminable in healthy elderly adults.

## METHOD

### Participants

The sample consisted of a total of 112 participants comprising four groups: university students ( $n = 40$ ; 20 men and 20 women), elderly volunteers ( $n = 39$ ), patients who displayed neuropsychological impairment but without prefrontal lobe indicators ( $n = 20$ ), and patients who displayed comparable neuropsychological impairment but with prefrontal lobe indicators ( $n = 13$ ). The mean for each group was 21 years (range = 19–30), 71 years (range = 65–80), 31 years (range = 20–40), and 30 years (range = 19–38), respectively.

More than 85% of the 33 patients had sustained CHI during industrial or motor vehicle incidents between 2.0 years and 3.5 years before the neuropsychological assessments. Designation as suffering from prefrontal lobe impairment required moderate to severe deficits (Jarvis & Barth, 1984) for Trails A, Trails B, and the Category Test but minimal deficits for other Halstead-Reitan tasks. There was no significant difference,  $F(1, 31) < 1.00$ ,  $p > .05$ , between the Halstead Impairment Index (Reitan & Wolfson, 1985) for the two clinical groups ( $M = 0.6$ ,  $SD = 0.2$ ). The patients had been referred from a variety of agencies.

All of the 10 patients within the prefrontal group for whom computer tomography (CT) X-ray images had been obtained (usually within 48 hr of the injury) exhibited evidence of prefrontal contusions, such as focal intracerebral hemorrhages within the left and the right (2 of the 10) frontal lobes or only the right (8 of the 10) frontal lobe and intraventricular hemorrhage that was confined to the anterior horns of the lateral ventricles. None of the 12 (of 20) patients for whom CTs were available from the non-prefrontal group showed anomalies within the anterior cerebrum, but all did exhibit hemorrhage or anomalous translucencies within the parietal or temporal lobes or their respective ventricular horns. The focal trauma was within the right hemisphere only for 10 of these cases.

The CSAT involved six blue lights that were mounted on the modified tops of black 35 mm film containers; each container and light was indiscriminable from the other. A wire from each light was connected to a control box that allowed any given light to be lit with each trial. The six lights were clustered together in the

middle of the table, and the experimenter sat behind a small screen that hid the control box.

The participant sat across the table from the experimenter. Six cards, each displaying a number between 1 and 6, were placed in a row in front of the participant. The participant was asked to point to any of the numbers when one of the lights was lit and to determine which number was associated with which light. The experimenter responded "no" to each of the participant's choice of numbers until it matched the appropriate light.

Each participant received a total of 15 blocks of trials. During each block, each light was lit in the same quasi-random order (i.e., the same light was never lit more than once per block). The total numbers of errors per block, until each light had been correctly identified with its appropriate number, were recorded. In addition, the numbers of blocks required before the participant displayed two successively correct blocks (no errors) were also recorded.

The primary design for the total number of errors was a two-way analysis of variance (MANOVA) with one level repeated (five components) and one not repeated (group). In order to minimize the probability of aberrant contributions from single blocks, the 15 blocks were segmented into five (3 blocks each) successive components. Because there was no significant sex effect, this variable was excluded. All analyses involved SPSS software on a VAX 4000 computer.

## RESULTS

A one-way analysis of variance (ANOVA) demonstrated statistically significant differences,  $F(3, 108) = 8.60, p < .001; \eta^2 = 0.44$ , between groups for the total numbers of errors during the 15 blocks of the CSAT. The means for total errors for the groups were 33.7 for university students ( $SD = 32.2$ ), 42.8 for elderly participants ( $SD = 42.5$ ), 48.8 for non-prefrontal patients ( $SD = 47.1$ ), and 107.4 for prefrontal patients ( $SD = 71.4$ ). Post hoc analysis (Scheffé Set A,  $p < .05$ ) indicated that the major difference was between the prefrontal group relative to the other three groups that did not differ significantly from each other. Because of the significant heterogeneity of variance (Bartlett Box = 4.72,  $p < .01$ ), a Kruskal-Wallis one-way ANOVA was completed; it also demonstrated the group differences,  $\chi^2 (df = 3) = 13.11, p < .01$ .

The MANOVA as a function of the five repeated components (three blocks each) and group reaffirmed the group main effect,  $F(3, 108) = 8.61, p < .001, \eta^2 = 19\%$ . Both the differences between components,  $F(4, 432) = 187.28, p < .001, \eta^2 = 63\%$ —that is, the learning curve and the interaction between learning and groups,  $F(12, 432) = 2.12, p = .01, \eta^2 = 6\%$ —were statistically significant. Post hoc comparisons revealed that the major source of the interaction was due to the

maintained error rate of the prefrontal patients compared to the elderly participants, university students, and non-prefrontal patients who did not differ significantly from each other. The results are shown in Figure 1.

Because of the heterogeneity of variance, square root transformations were completed for the CSAT error scores. The multivariate test for homogeneity of the dispersion matrices was no longer significant. A MANOVA of the transformed scores verified the presence of the group effects,  $F(3, 108) = 7.74, p < .001, \eta^2 = 18\%$ , the improvement (learning) over blocks,  $F(4, 432) = 243.84$ , and the Block  $\times$  Group interaction,  $F(12, 432) = 2.72, p = .001$ .

## DISCUSSION

These results do not support the hypothesis that quantitative deterioration in selective prefrontal functions is always associated with normal aging. Healthy elderly participants did not differ significantly from university students or from patients with brain injury in areas other than the prefrontal lobes on a task that required serial order, memory, spatial association, self-monitoring, and flexibility.

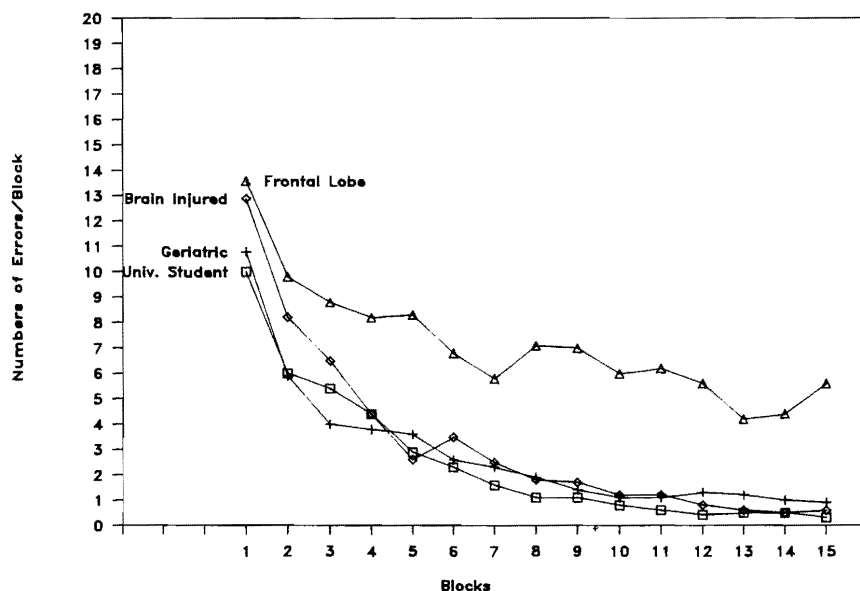


FIGURE 1 Total numbers of errors per block during a conditioned spatial association task for healthy elderly participants, university students, brain injured (non-prefrontal) patients, and prefrontal lobe injured patients.

These results are comparable to those of Willis, Yeo, Thomas, and Garry (1988) who found no overall age-related differences for the Category Test (a classical inference of "prefrontal" integrity) once health status had been accommodated.

That the CSAT is sensitive to prefrontal dysfunction was demonstrated by the relatively poorer performance of patients with clinical indicators of traumatic injury to this region. Because the prefrontal group and the non-prefrontal group did not differ significantly within respect to general brain impairment, as defined by the Halstead-Reitan Impairment Index, the likelihood of a nonspecific effect is minimal. We were also careful to differentiate patients, *a priori*, on the bases of both their specific impairment for traditional indicators of prefrontal lobe function (Trails A, Trails B, and the Category Test) as well as the available CT information.

As expected, the patients who had sustained CT-detectable injury to the prefrontal lobes and had exhibited impairment for neuropsychological tests that infer the integrity of their function did not benefit from the immediate feedback. They often perseverated with previously unrewarded sequences and exhibited a marked absence of age-appropriate, self-monitoring capacity. These deficits can be masked or occluded within traditional psychological assessments. In our experience, even these participants often score within the average range for intellectual (IQ) tests because they are administered within highly structured settings.

The failure to find a significant difference among the healthy older adults, university students, and patients who had not sustained objective prefrontal injury does not support the hypothesis that normal aging must be associated with the emergence of prefrontal dysfunction. However, there is a caveat to this conclusion. Performance during the CSAT was evaluated according to errors and not as a function of time required to achieve criterion. One would expect that healthy elderly patients would display slower reaction times (and more time required to acquire the same level of proficiency) compared to university students. Such a result would be compatible with our general qualitative observations.

We would also expect that patients with CHI, even without prefrontal dysfunction, should display slower reaction times compared to normal age-paired controls (Parker, 1990). This would be compatible with the hypothesis that diffuse traumatic brain injury in particular simply accelerates the aging process (Gedye, Beattie, Tuokko, Horton, & Korsarek, 1989; Persinger, 1995, *in press*) within the brain because of the diffuse (statistical) neuronal drop-out or the atrophy of distal dendrites that is associated with the age-dependent reduction in neuronal soma (Finch, 1994). If this assumption is valid, then the consequences of fatigue and the duration of the stimulus (a brief presentation vs. one that is protracted over several hours) would not be conspicuous within a single, brief test session. In subsequent studies the differential effects of speed versus proficiency during various portions of the cognitive day on the CSAT might be investigated.

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